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The effect of external ankle support on knee and ankle joint movement and loading in netball players

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ABSTRACT

Objectives: External ankle support has been successfully used to prevent ankle sprains. However, some recent studies have indicated that reducing ankle range of motion can place larger loads on the knee. The aim of this study was to investigate the effect of external ankle support (braces and high-top shoes) on the ankle and knee joint loading during a netball specific landing task.
Design: A repeated measure design.
Methods: High performance netball players with no previously diagnosed severe ankle or knee injury ($n = 11$) were recruited from NSW Institute of Sport netball programme. The kinematic and kinetic data were collected simultaneously using a 3-D Motion Analysis System and one Kistler force plate to measure ground reaction forces. Players performed a single leg landing whilst receiving a pass while wearing a standard netball shoe, the same shoe with a lace-up brace and a high-top shoe.
Results: Only the brace condition significantly reduced the ankle range of motion in the frontal plane (in/eversion) by 3.95 ± 3.74 degrees compared to the standard condition. No changes were found for the knee joint loading in the brace condition. The high-top shoes acted to increase the peak knee internal rotation moment by 15%. Both the brace and high-top conditions brought about increases in the peak ankle plantar flexion moment during the landing phase.
Conclusions: Lace-up braces can be used by netball players to restrict ankle range of motion during a single leg landing while receiving a pass without increasing the load on the knee joint.

1. Introduction

About 411,300 Australians aged 15 years and over play netball on a regular basis, making it the most popular team sport in Australia.[1] Netball is a physically demanding sport in which speed, strength, fitness and flexibility are important. The incidence of injury in netballers has been reported to be about 14 injuries per 1000 player hours.[2] The most common site of injury is the lower extremity, with the ankle joint accounting for the majority of the injuries sustained in recreation and elite netball competitions.[3,4] The knee joint is the second most common in terms of injury incidence[3,4] but the most significant in terms of costs and disability.[5]

External ankle support strategies, such as prophylactic braces and high-top shoes, are commonly used in an attempt to protect the ankle or prevent further injury.[6] Several biomechanical investigations have demonstrated that ankle braces are effective in preventing, decreasing, or slowing the motions that may cause injury to the lateral ankle ligaments.[7–9] The use of ankle braces has been shown to significantly reduce the occurrence of ankle sprains, especially in people with previous ankle injuries.[10–12] The stabilizing effect of high-top shoes is less obvious from previous literature with limited biomechanical investigations suggesting a restriction in the ankle inversion range of motion (ROM).[13,14] Other studies have reported that the restrictive effect of high-top shoes is considerably less than the ROM restriction imposed by prophylactic ankle stabilizers or ankle taping.[15] This being said, Hume et al.,[6] have suggested that standard (low-cut) shoes should be discouraged for use in netball, and high-top shoes have been recommended for sports such as basketball[16] or those involving sideways cutting movements.[17]

Although it is suggested that ankle braces and high-top shoes may be effective in reducing the likelihood and severity of ankle sprain-type injuries, restricting ankle movements may increase the risk of injuries to proximal joints such as the knee. Recent studies have reported that restricting the movement of the ankle in the

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frontal plane can act to increase the peak knee internal rotation moments,[18,19] which may contribute to the development of knee injuries.[20,21]

The mechanism of knee injury in netball players has often been described as a sudden stop or an incorrect landing.[4,22,23] One of the suggested mechanisms of knee injury is rapid deceleration, twisting and hyperextension of the knee after landing[24] which may potentially occur during single leg netball landings. This may be because upon receiving a pass a player must rapidly reduce horizontal velocity and maintain a position of balance and stability so that the footwork rule is not violated. As knee injuries are the second most common injury in netball players and braces and high-top shoes are recommended,[6] it is important to investigate the effect of high-top shoes and braces on knee joint loading during a netball specific landing task.

The primary objective of this study was to compare knee joint moments incurred during a single leg landing task whilst wearing a standard netball shoe, a standard netball shoe with an ankle brace, and a high-top shoe. We hypothesized that the brace and the high-top shoe would increase knee joint loading compared to the standard shoe. Our secondary aim was to quantify the effect of the brace and the high-top shoe on the ankle joint movement and loading. We hypothesized that the brace and the high-top shoe would restrict the peak ankle joint angles, ROM and position at landing and increase the knee joint moments.

2. Methods

Forty-four players from the New South Wales Institute of Sport (NSWIS) netball programme completed a self-administered screening questionnaire which sought information about their experiences with knee and ankle problems. Nineteen players were ineligible for the study because they satisfied one or more of the following exclusion criteria: (1) a history of knee or ankle surgery; (2) knee or ankle pain in the previous six months that required consultation with a medical practitioner and/or caused a formal netball training session or game to be missed; or (3) current knee or ankle pain or instability that would have prevented performance of the landing task at the required intensity. Twenty-five players who met the inclusion criteria were invited for a biomechanical assessment of their landing technique but only 12 were able to attend a testing session. Players could not attend a testing session because of study or work commitments, unrelated injuries or commitments with the national team. Data analysis was performed on 11 players because data for the netball shoe condition for one player could not be analyzed due to technical problems. Average age, height and mass of the included players were 18.3 ± 1.8 years, 178.5 ± 4.1 cm and 70.1 ± 8.2 kg respectively. All test procedures were approved by the Human Research Ethics Committee at The University of Sydney, and all participants gave their written informed consent before data collection.

A three-dimensional kinematic analysis was performed to track the position of all segments of the right lower limb (pelvis, thigh, shank, rear foot and fore foot, respectively) in space. The data were collected at 200 Hz using a 14-camera 3-D motion analysis system (Cortex, Motion Analysis Corporation, Santa Rosa, CA, USA). Additionally, one Kistler force plate (Kistler Instrumente AG, Winterhur, Switzerland) sampling at 1000 Hz was used to simultaneously measure ground reaction forces. Each subject had twenty-one reflective surface markers taped to specific anatomical landmarks on the pelvis, thigh, shank and shoe using hypoallergenic tape. Markers were placed on the sacrum, right and left anterior superior iliac spine, right and left greater trochanter, right mid-thigh, medial and lateral femoral epicondyle, upper, lower and lateral tibia, medial and lateral malleoli, lateral, medial and posterior calcaneus, navicular, 1st and 5th metatarsal joint, the hallux, and on the left posterior calcaneus.

Motion of the rear-foot was determined using a device previously described by Attwells and Smith (Fig. 1).[25] It consisted of an array of three markers mounted onto a rigid shaft that attached to the calcaneus via a flexible metal stirrup. The stirrup provided a large contact area around the calcaneus and was secured using double sided adhesive tape and strapping tape. The wand extended posteriorly through a 14 mm hole in the rear of the shoe counter. The brace used in this study had no heel cup so the stirrup could be placed on the calcaneus. All players were provided with a pair of socks with a hole in the area of the heel to provide access to the calcaneus.

The movement pattern assessed was a single leg landing whilst receiving a pass. Each player was instructed to use a 5 m straight line approach to the landing area at a self-selected speed. The player 'leapt' from her left leg and landed on her right leg on the force plate. As the player was about to land she received a chest pass that was distributed with a flat trajectory by a tester who was positioned approximately 3 m from the landing area and at a 5 degrees angle relative to the approach direction. After landing the player was permitted to step forward with her left leg but no further steps were allowed. Players were allowed as many practice trials as necessary to become familiar with the procedures and testing environment. Once data collection commenced players were required to complete 8–10 successful trials. A trial was considered successful if it satisfied the requirements of the task and the right foot landed within the border of the force plate. Players performed this movement with a standard netball shoe (Ignite3, Ascics) (standard condition), the same netball shoe with a lace-up brace (E-Professional) (brace condition) and a high-top shoe (Jordan, Nike) (high-top condition). The order of the conditions was randomized.

Kinematic and kinetic data were processed using Visual3D software (C-motion, Rockville, MD, USA). The lower extremity segments were modelled as a frustra of right cones while the pelvis was modelled as a cylinder. Anthropometric data was based on Dempster. Internal moments were calculated at the proximal end of the distal segment of each joint. The local coordinate systems of the pelvis, thigh, leg, rearfoot and forefoot were derived from the standing calibration trial. Coordinate data were low-pass filtered using a fourth-order Butterworth filter with a 6–15 Hz cut-off frequency. Ground reaction force data were low-pass filtered using a fourth-order Butterworth filter with a 20 Hz cut-off frequency.

Six degrees-of-freedom for each segment were determined from the segment's set of reflective markers. Subsequently, lower extremity 3-D joint angles were calculated using a Xyz Cardan rotation sequence.

All data were time-normalized between ground contact for the right foot and ground contact for the left foot. Ground contact for the right foot was determined using the vertical ground reaction force with a threshold of 20 N while ground contact for the left foot was determined by the lowest point of the left calcaneal marker. Several trials from 2 players needed to be eliminated due to the wand hitting the floor or due to the player landing on the border of the force plate. It was therefore decided to analyze the first four good trials from each subject for each condition Discrete variables were extracted from each individual trial and averaged for each player. The individual mean curves were averaged across conditions to produce ensemble curves.

Histograms of all variables were visually inspected for normality. Comparisons between the brace and the standard shoes and between the high-top shoes and the standard shoes were made using paired *t*-tests for normally distributed continuous data and the Kruskal–Wallace test for non-normally distributed continuous data. Dependent variables for the ankle joint loading were the ankle